

Emission Isolation Flux Chambers and Risk Assessments: Applications for Cost-Effective Risk Assessment and Risk Management

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Volatile Organic Compounds (VOCs) are a major soil and ground water contaminant at many Department of Energy (DOE) sites. These compounds are characterized by their high volatility, allowing them to easily partition into air. As a result, the inhalation pathway can be a major pathway by which onsite adult workers are exposed to these contaminants. This is true even if the underlying contaminated aquifer is not used as a drinking water source. For exposure to adults onsite (which we term AOS exposure), it is necessary to estimate the contribution of VOCs to the inhalation air as a result of flux of VOCs from contaminated ground water through the subsurface, and the flux of VOCs from contaminated soil through the subsurface. If the contaminants underlie a building, flux into the building must also be estimated. Due to the complexity of these fluxes, simple, health conservative models are often used to estimate an exposure point concentration in air. Such estimates might result in the implementation and performance of remediation where it's arguably not necessary. However, an alternative is to directly measure flux from the subsurface using emission isolation flux chambers.

At Lawrence Livermore National Laboratory (LLNL), we are investigating the use of emission isolation flux chambers for use in our risk assessment and risk characterization activities at Site 300. Site 300 is LLNL's high-explosive test facility. At the General Services Area (GSA) operable unit at Site 300, VOCs are the primary contaminant found in soil/rock and ground water. An initial baseline risk assessment was completed in 1993. This risk assessment was revised in 1994 using results from the emission isolation flux chamber techniques discussed here. This allowed us to compare the risk analyses conducted using results of the two techniques.

The original baseline risk assessment was completed using characterization data consisting primarily of ground water and soil/rock analytical results. For this initial assessment, we relied on simple, conservative models to estimate the risk of inhalation of volatile organic compounds (VOCs) in both outdoor and indoor air. These models were endorsed for use in Superfund risk assessments by the U.S. Environmental Protection Agency. To estimate the flux rate of contaminants from the subsurface into outdoor air, we first calculated a 95% upper confidence limit (UCL) of the mean concentration of the VOC from available contaminant concentration data to a depth of 12 ft. This 95% UCL was then used in a model from Hwang *et al.* (1986) to estimate an average volatilization flux rate. This model was developed to describe volatilization flux of a contaminant through a porous soil where the soil surface is exposed to a relatively uncontaminated, turbulent atmosphere. This is an equilibrium-based model that assumes the 95% UCL represents an unlimited contaminant reservoir. It does not consider contaminated ground water which may also occur in the area. The estimated flux rate was then used with a simple Gaussian-dispersion model by Turner (1982) to calculate an exposure point concentration.

For diffusion into a building, since the building acts as a barrier, we first used a simple equilibrium model based on Henry's law to estimate the concentration of a VOC at the soil surface underneath a building (McKone, 1992). Again, we used the 95% UCL of contaminant data to a depth of 12ft. We then estimated diffusion through the concrete using a diffusion model which considered the thickness of the concrete slab, along with a factor representing the fraction of the slab composed of cracks. Finally, an exposure point concentration was estimated by considering the surface area of the building and the ventilation rate. Using the results from these models, the resulting additional cancer risk from inhalation of indoor air was calculated to be 1×10^{-5} , and that for outdoor air was 1×10^{-4} . Although these risk estimates are not excessively high, the U. S. Environmental Protection Agency Region IX currently uses 1×10^{-6} as a "point-of-departure" for evaluating cleanup alternatives. Thus, our estimated risk would have required us to expend considerable effort developing and evaluating cleanup alternatives.

To more accurately estimate the rate of VOC flux from the subsurface, in the fall of 1994 we collected flux data from the GSA using emission isolation flux chambers. Data collected from flux chambers has the advantage of considering flux from all sources underlying the surface, such as soil and ground water. In addition, it is not necessary to assume a depth from which flux is assumed to occur. As a result, direct soil flux measurements more realistically represent true VOC flux. The direct soil flux measurements were obtained using the emission isolation flux chambers with samples collected in SUMMA™ canisters for certified analysis as recommended by the U.S. EPA methodology (U.S. EPA 1986). The emission isolation flux chamber was placed on the ground surface, and VOC soil flux emissions entered the open bottom of the chamber. Clean dry sweep air was added into the chamber at a metered rate. Within the chamber a fan mixed the sweep air with emitted VOC vapors. When the concentration of the VOC soil flux emissions and the sweep air reached equilibrium, a sample was collected in a SUMMA™ canister for analysis. A VOC flux rate was calculated using the 95% UCL calculated from the validated analytical results along with the sweep flow rate and the surface area enclosed by the chamber.

In order to estimate exposure point concentrations from the resulting flux, we used carefully selected and modified exposure models which were more realistic for our scenario than those used in the initial assessment. To estimate an outdoor exposure point concentration, we used a box model for outdoor air taken from the American Society of Testing and Materials (ASTM 1994). This model is more appropriate than standard air dispersion modeling methods since the estimated exposure point concentrations in outdoor air are intended only for receptors in the immediate vicinity and directly over the GSA. In the case of indoor air, since the building of interest stored and used VOCs, it was not possible to take flux measurements directly inside the building. Therefore, direct flux measurements were obtained from the soil surface surrounding the outside of the building, in the area where the highest contaminant concentrations in soil were detected. A slab diffusion-limited flux model and an indoor box model, also from ASTM (1994) was then used. Using these techniques, we estimated an indoor air cancer risk of 7×10^{-7} and an outdoor air cancer risk of 2×10^{-7} .

This process shows the natural progression that many risk assessments take. Very conservative, simple models are initially used to estimate risk. If these calculations yield an estimated risk which is unacceptable, either more realistic characterization data is collected and more realistic models are used, or the development of remedial alternatives may be required. However, this can often be perceived as "model shopping", and may not be accepted by regulatory agencies or the community. In our case, we were successful in using our revised risk estimates to eliminate the outdoor inhalation exposure pathway from consideration during the development of remedial alternatives for this site. However, negotiations are still continuing concerning the revised indoor inhalation risk estimates. Therefore, our experience suggests that program managers may want to consider using emission isolation flux chambers initially, since our data shows that simple, conservative models can greatly overestimate risk.

We are also developing techniques to use emission isolation flux chambers to monitor localized areas in which we have put in place administrative controls to reduce inhalation exposure. By monitoring these areas as we remediate the underlying contaminated soil and ground water, we will be able to adjust our administrative controls to appropriately reduce exposure and the resulting risk.

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